Gene action of blast disease reaction and grain yield traits in finger millet

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ABSTRACT

Gene action of blast reaction, yield and yield associated traits in finger millet were studied using a 4x4 North Carolina Design II mating scheme. The four female and four male parents and their 16 crosses were evaluated at Alupe and Kakamega in western Kenya in a randomized complete block design under both artificially induced and natural disease pressure. General combining ability (GCA) and specific combining ability (SCA) estimates of the traits were calculated to determine the genotypes breeding value. The GCA variance predominated over SCA variance for all traits except finger width hence these traits can be improved through selection. With high, desirable GCA effects, male parent KNE 392 and female parents KNE 744 and IE 11 are suitable for blast resistance breeding while male parent Okhale 1 is suitable for grain yield improvement. The frequency distribution for the segregating F2 generation for the three blast types differed within and between crosses which could be due to differences in gene numbers or gene combinations being expressed in the different parents used. Convergent crossing or gene pyramiding for durable resistance could be possible.

INTRODUCTION

Finger millet blast (Fig 2) caused by the fungus *Magnaporthe grisea* (anamorph *Pyricularia oryzae*) is the major biotic constraint in finger millet productivity in East Africa. Most cultivated landraces are susceptible to the disease with grain yield losses of up to 60% (Pande et al., 1995; Obilana and Manyasa, 2002). For an effective breeding strategy, knowledge of the nature of gene action determining inheritance of target traits is necessary (Krishnappa et al., 2009). Knowledge of combining ability helps determine whether trait improvement can be achieved through recurrent selection or convergent crossing or through hybrid breeding to exploit heterosis. The objectives of this study were to generate information on the combining ability and trait inheritance of eight finger millet parental lines and their progenies.

Experimental design and crop management

The 16 F2 families and their 8 parents including three checks (KNE 479-susceptible to blast, U 15-released resistant and Ikhulule – local landrace) were evaluated at 2 locations in Kenya: Alupe 1189 masl, mean annual rainfall of 1100 mm; mean temperature 24.0°C and Kakamega - 1535 masl, mean annual rainfall 1921 mm, mean temperature 20.5°C. Separate inoculated and non-inoculated field trials were planted at each of the two locations in a Randomized Complete Block Design (RCBD) in three replications ,two rows per plot each 3 m in length with 0.4 m between rows. Fertilizer was applied as per recommended rates. However, in the inoculated trial an extra 10 kg N ha-1 was applied to boost blast infection as suggested by Kurschner et al. (1992).

Enhancing epiphytotic conditions

A broad-based inoculation technique incorporating finger millet crop debris collected the previous season, infector rows, artificial inoculation and supplemental irrigation (Pande et al., 1995; Kiran Babu et al., 2013) was implemented. Inoculum was prepared from a single-spore representative culture of *M. grisea* isolated from blast infected samples collected from the finger millet fields in the previous season and cultured on oat meal agar (OMA) medium (Fig 1) (Kiran Babu et al., 2013) plus complete meal at 26±1ºC for ten days. The spore suspension was adjusted to 1×10^5 spores/ml with the aid of a hemocytometer before inoculating the plants during the early evening hours on twenty day old seedlings and at pre-flowering.

Fig 1. An eight day old culture of *Magnaporthe grisea*

Fig 2. Leaf blast, Neck blast and Finger blast symptoms

Data analysis

ANOVA

All analyses were done using PROC GLM procedures (SAS, 2008) with locations as random effects and entries as fixed effects. Data were transformed by subtracting the environment mean and dividing by standard errors of the corresponding environment. ANOVA for combining ability was done using procedure by Kempthorne (1957). The general predicted ratio was estimated (Baker (1978):

Combining ability and general predicted ratio (GPR)

General combining ability (GCA) effects:

$GCA_f = \bar{x}_f - \mu$, and $GCA_m = \bar{x}_m - \mu$ where: GCA_f and GCA_m= General combining ability estimates of female and male parents, respectively, $\bar{x}_m$ and $\bar{x}_{mf}$ = Mean of male and female parents, respectively $\bar{x}_f$ - μ = Overall mean of crosses in the trial

Specific combining ability (SCA) effects:

$SCA_{fm} = \bar{x}$- E $(\bar{x})$ $= \bar{x}$- $[GCA_f + GCA_m + \mu]$ where: SCA_{fm}= specific combining ability of the cross between female, f and male, $\bar{x}$= Observed mean value of the cross $E(\bar{x})$ = Expected mean value of a cross based on the two GCAs of its parents.

General prediction ratio (GPR) based on Baker (1978)

RESULTS

Significant differences (P<0.05) for the three blast types were recorded among the parents across locations. Mean percent increase across the two locations was 32.3% for leaf blast, 19.4% for neck blast and 26.4% for finger blast under inoculation relative to natural infection. . Male parent Okhale 1 had low percent disease increase.

Mean sum of squares for combining ability

Differences between parents and between crosses were significant (P<0.05) for 13 of the 14 traits, the exceptions being number of fingers and grains per spikelet, respectively (Table 1). Significant (P<0.05) GCA (females) and SCA variances were recorded for leaf, neck and finger blast (Table 1). GPR values were 0.8, 0.8 and 0.9 for leaf, neck and finger blast, respectively. GCA estimates were also predominant for days to flowering and maturity, plant height, grain yield ha-', and 1000-grain mass.

GCA effects

GCA effects varied among the parents (Table 2). Female parent KNE 744 had significant (13.<0.05), desirable negative GCA effects for leaf blast (-0.36), neck (-0.67) and finger blast (-1.04). Female parents IE 3104 and IE 11 had negative GCA effects for at least one of the blast types. Female parent KAT FM 1 had significant (P<0.05) positive GCA effects for the three blast types (0.47, 0.77 and 0.55 for leaf, neck and finger blast, respectively). Male parent KNE 392 had negative GCA effects for the three blast types whereas Okhale 1 had significant (P<0.05) positive GCA effects for grain yield ha-1 (0.27).

Segregation for blast severity

Frequency distribution for the three blast types differed within and between crosses (Fig 3)

Table 1: Mean squares for combining ability for selected traits of finger millet across two test locations

Source	Df	Lblast	Nblast	Fblast	Gyld	Daf	Dam	Pht	Fingers	1000 mass
Loc	1	5.25**	66.02**	41.71**	52.84**	3239.50**	2558.67**	26490.28**	166.84**	8.11**
Rep/loc	4	2.46**	2.85*	1.82*	1.25**	81.08*	30.36	101.93**	0.74	0.49**
Treat	23	1.90**	10.30**	12.19**	1.18**	200.92**	185.09**	491.17**	2.25**	0.25**
Parents	7	2.42*	16.69**	22.63**	1.35**	262.04**	235.05**	1261.74**	1.04	0.33**
Crosses	15	1.53**	7.65**	7.95**	1.15**	183.79**	174.08**	155.18**	2.57**	0.24**
Parents x Crosses	1	3.90*	5.28*	2.80*	0.45*	30.03	0.42	136.95*	5.84**	0.02
Female (GCA_f)	3	2.885**	9.27**	12.71**	0.25	284.04**	289.98**	191.27**	2.43*	0.39**
Male (GCA_m)	3	0.412	0.38	1.02	1.12**	37.96	68.51**	194.22**	3.96**	0.05
Female*Male (SCA)	9	1.44**	9.54**	8.67**	1.46**	198.98**	170.64**	130.14**	2.16**	0.25**
Loc x Treat	23	0.72*	1.37	1.37*	0.27*	30.22	26.57*	52.58*	1.96**	0.10
Loc x Parents	7	0.83	2.12	3.11*	0.32	57.33	26.19	37.86	1.42*	0.15
Loc x Crosses	15	0.70**	1.08*	0.59	0.26	19.02	28.13*	62.87*	2.14**	0.08
Loc x Females	3	0.27	0.39	0.23	0.13	22.04	23.46	130.35**	6.68**	0.06
Loc x Males	3	0.60	0.82	1.00	0.38	3.68	46.59*	23.28	0.26	0.02
Loc x Female x Male	9	0.87*	1.40*	0.57	0.26	23.13	23.54	53.58	1.26	0.10
Error	92	0.33	1.05	0.74	0.15	27.21	14.98	27.11	0.65	0.06
General predicted ratio (GPR)		0.8	0.8	0.9	0.7	0.7	0.7	0.9	0.4	0.7

Df-Degrees of freedom; Lblast-Leaf blast;, Nblast-Neck blast; Fblast-Finger blast; Gyld-Green yield (t ha-1); Daf-Days to flowering; Dam-Days to maturity; Pht- Plant height (CM); Fingers- Fingers/panicle, 1000 mass-1000-grain mass. ** Significant at P<0.01; * Significant at P<0.05

Table 2: General combining ability (GCA) effects of parents

	Leaf Blast	Neck blast	Finger blast	Gyld	Daf	Dam	Pht	Fingers	1000 mass
GCA females									
KAT FM 1	0.47**	0.77**	0.55**	0.13	-3.03**	-4.36**	3.70**	0.11	0.11*
IE 3104	-0.07	0.19	0.46**	0.00	-2.70**	0.3	-2.56*	0.36*	-0.16**
KNE 744	-0.36**	-0.67**	-1.04**	-0.02	4.01**	4.14**	-1.80	-0.09	-0.05
IE 11	-0.05	-0.29	0.03	-0.12	1.72	-0.07	0.66	-0.39*	0.10
GCA males									
OKHALE 1	0.04	-0.06	0.03	0.27**	0.34	1.51*	4.06**	0.41*	-0.04
KNE 796	0.06	0.17	0.28	0.03	-1.41	-1.16	-0.15	0.16	0.03
KNE 392	-0.19	-0.13	-0.10	-0.04	-0.49	-1.74*	-2.24*	-0.01	-0.03
P 224	0.10	0.02	-0.20	-0.26**	1.55	1.39	-1.67	-0.55**	0.05
SE (gi)	0.101	0.156	0.148	0.078	0.918	0.745	1.079	0.170	0.051
SE(gij)	0.142	0.220	0.209	0.110	1.298	1.053	1.526	0.240	0.072

Gyld-Grain yield (t ha-1), Daf-Days to flowering, Dam-days to maturity, Pht-Plant height, Fingers- Fingers/panicle, 1000 mass –1000-grain mass. ** Significant at P<0.01; * Significant at P<0.05

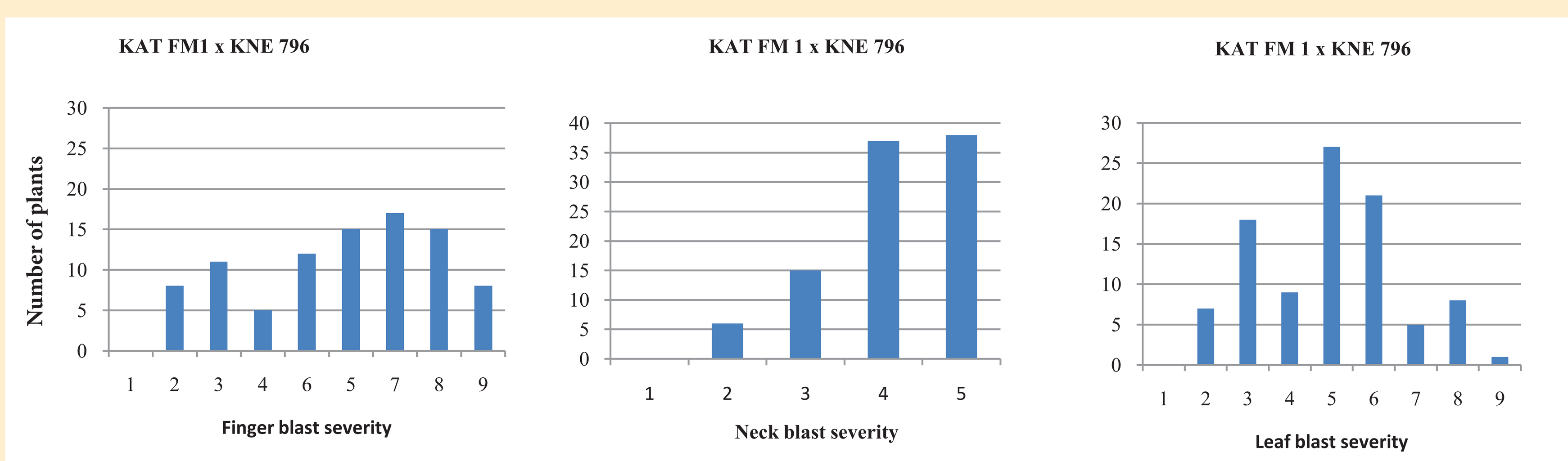

Figure 3. Frequency distribution of blast scores (leaf, neck and finger) in the F2 generation of cross KAT FM 1 x KNE 796

DISCUSSION

Both additive and non-additive gene effects influenced inheritance of blast and all yield traits studied except fingers per panicle which was controlled mainly by non-additive gene effects and grains per spikelet which was controlled mainly by additive gene effects. Desirable significant negative GCA estimates for leaf, neck and finger blast were detected in female parent KNE 744 and negative effects in male parents KNE 392 for leaf and neck blast, P 224 for finger blast and Okhale 1 for neck blast. Female parents KAT FM 1 and IE 3104, and male parents KNE 392 and KNE 796 had the best desirable negative GCA effects for imparting earliness. Desirable positive GCA effects for grain yield ha-1 were exhibited only by male parent Okhale 1 and correspondingly the best crosses with high mean grain yield ha-1 had Okhale 1 as male parent. The presence of plants more resistant than their parents was evident in the transgressive segregation observed in many of the crosses for the three blast types, especially in crosses where at least one parent had desirable negative GCA effects. The low frequency of transgressive effects observed in some crosses may be due to similar gene frequencies in the parents. The difference in segregation patterns between crosses may indicate the presence of different resistance genes in the different parents used which would call for gene pyramiding for durable resistance (Sridhar and Singh, 2001).

Conclusion

Parents KAT FM 1, KNE 744 and KNE 392 will be useful combinations in breeding for the three blast types whereas Okhale 1 will be useful in breeding for grain yield improvement. These results confirm the potential in the local germplasm for sourcing valuable parental stocks for development of high yielding and blast resistant finger millet genotypes in East Africa and will help formulate an effective breeding strategy.

References

Baker (1978); Kempthorne (1957); Kiran Babu et al., (2013); Krishnappa et al., (2009); Kurschner et al. (1992); Oduori and Kanyenji (2007); Obilana and Manyasa, (2002); Pande et al., (1995) ; Sridhar and Singh, (2001)

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